Meeting with the
Alliance of Automobile Manufacturers and Global Automakers

TECHNICAL UPDATE ON THE MIDTERM EVALUATION

June 22, 2017
Office of Transportation and Air Quality
National Vehicle and Fuel Emissions Laboratory

Meeting Request & Agenda

- The Alliance of Automobile Manufacturers and Global Automakers requested a meeting with the purpose of "understanding EPA's ongoing efforts and developments since January."
- The trade associations indicated they would plan to present slides on the topics below, and would like to hear updates from EPA on any ongoing work in these areas
- Suggested Agenda:

GlobalAutomakers AUTO ALLIANCE

Industry and Agencies Meeting
June 22, 2017 1:00pm -3:00pm EST

Draft Agenda

1. Welcome and Introductions / Antitrust & Confidentiality Reminder
2. Discussion Items
   - 2.1 2016 Vehicle Performance
   - 2.2 Technology Assessment
   - 2.3 ALPHA Model Discussion
   - 2.4 LPM Model Discussion
   - 2.5 OMEGA Model Discussion
   - 2.6 Evaluation of Costs
   - 2.7 Consumer Acceptance
   - 2.8 Economic Impacts
3. Close

EPA's Reconsideration of the MTE Final Determination

March 15, 2017 - EPA Administrator Pruitt and DOT Secretary Chao announced a Federal Register Notice stating that EPA will reconsider the Final Determination published in January 2017:

> *" … EPA has concluded that it is appropriate to reconsider its Final Determination in order to allow additional consultation and coordination with NHTSA in support of a national harmonized program."*

> *"In accord with the schedule set forth in EPA's regulations, the EPA intends to make a new Final Determination regarding the appropriateness of the MY 2022-2025 GHG standards no later than April 1, 2018."*

EPA's On-going Work

- In following with the Administrator's decision to reconsider the Final Determination, EPA is continuing to assess the most up-to-date information.
- The technical staff's goal is to provide the Administrator with updated technical information that can be used in the reconsideration of the Final Determination
- Updated technical information is being obtained from multiple sources, including:
  - *Stakeholder outreach*
  - *EPA-sponsored research*
  - *Technical conference participation*
  - *Reviews of the literature and other published reports*
  - *Monitoring current light-duty compliance, technology trends, and market developments*

Technical Conferences from which EPA has Gathered Data/Information
(since January 2017)

- Advanced Automotive Battery Conference
- Vienna Motor Symposium
- CAR Powertrain Roundtable
- Great Designs in Steel
- 2017 Low Voltage Vehicle Electrification Summit
- Society of Plastic Engineers AUTO EPCON
- Advanced Thermal Management Systems conference - ITB Group
- Detroit Advisory Panel of the Automotive/Petroleum Industry Forum
- Clemson University Global Tire Conference
- ICCT/Bipartisan Policy Center: International Competitiveness and the Auto Industry: What's the Role of Motor Vehicle Emission Standards?
- CTI Symposium - Transmissions
- Association of Environmental & Resource Economists Summer Conference
- Society for Benefit Cost Analysis
- SAE Hybrid and Electric Vehicle Technologies
- SAE Government/Industry
- SAE World Congress
- SAE High Efficiency IC Engine
- SAE Light-duty Forum
- Automotive World Fuel Economy Detroit (Megatrends)
- Global Automotive Lightweight Materials (GALM)
- University of Wisconsin Engine Research Center Symposium - Impact of Future Regulations on Engine Technology

➢ EPA has collected numerous technical papers/presentations from these conferences which we continue to review for new information

Cost Studies

FEV tear-down cost studies in process:

- Diesel
  - 8 Cylinder Gas to 6 Cylinder Diesel
  - 6 Cylinder Gas to 4 Cylinder Diesel
  - 4 Cylinder Gas to 4 Cylinder Diesel
- Turbo Downsize
  - 8 Cylinder NA to 6 Cylinder Turbo
  - 6 Cylinder NA to 4 Cylinder Turbo
  - 4 Cylinder NA to 4 Cylinder Turbo
- CVT
- High Efficiency Gearbox (HEG)
- Update of databases used to inform previous cost studies
  - e.g., material costs, labor rates, adjust to 2016$, etc.

In-depth Work Underway to Evaluate Advanced Powertrains

Vehicle benchmarking:

- 2016 Chevy Malibu w/1.5 liter GDI-turbo-charged w/6-speed AT
- 2016 Acura ILX w/dual-clutch transmission with torque converter
- 2017 Ford F150 w/10 speed AT

Engine benchmarking:

- 2016 Honda Civic 1.5 liter GDI-turbo-charged 10.6:1 w/ CVT
- 2016 Mazda CX-9 2.5 liter GDI-turbo-charged w/ 6-speed AT
- 2018 Toyota Camry with 2.5 liter Toyota New Global Architecture (TNGA) engine

Demonstration and modeling:

- Demonstration of cooled EGR on a modified European Mazda 2.0 liter GDI naturally-aspirated 14:1 CR engine
- GTPower modeling of a 2012 PSA 1.6 liter GDI-turbo-charged engine with cooled EGR and an advanced turbo
- GTPower modeling of a 2016 Honda Civic 1.5 liter GDI-turbo-charged 10.6:1 CR engine
- ALPHA model comparison of several CVTs

ALPHA modeling of all vehicles included in above component and vehicle benchmarking.

Status of Vehicle Benchmarking Work

1. **2016 Chevy Malibu w/1.5 liter GDI-turbo-charged w/ 6-speed AT**
   - Vehicle has been procured, instrumented and testing is complete
2. **2016 Acura ILX w/dual-clutch transmission with torque converter**
   - Vehicle has been procured, instrumented and initial testing is complete
3. **2017 Ford F150 w/10 speed AT**
   - Vehicle has been procured and is being prepped for testing
   - Plan to evaluate transmission shift strategy and efficiency

Status of Engine Benchmarking Work

1. **2016 Honda Civic 1.5 liter GDI-turbo-charged 10.6:1 CR w/ CVT**
   - Goal of benchmarking: Confirm Honda's publically shared efficiency map and understand the engine's technology and combustion strategy
   - Chassis testing is completed, and engine dyno mapping is nearly complete
   - Data review and engine benchmarking report are underway
   - Initial ALPHA vehicle validation of the Honda Civic is complete
   - Currently investigating various methods to conduct CVT powertrain testing
2. **2016 Mazda CX-9 2.5 liter GDI-turbo-charged w/ 6-speed AT**
   - Goal of benchmarking: Obtain engine efficiency and operational maps
   - Chassis testing completed
   - Engine installed in test cell and initial testing has begun
3. **2018 Toyota Camry with 2.5 liter Toyota New Global Architecture (TNGA) engine**
   - Goal of benchmarking: Confirm Toyota's publically shared efficiency map (for non-HEV applications) and understand the engine's technology and combustion strategy
   - Plan to procure vehicle within the next month

Status of Demonstration and Modeling Work

1. **Demonstration of cooled EGR on a modified European Mazda 2.0 liter GDI naturally-aspirated 14:1 CR engine**
   - Follows up on validation work described in SAE 2017-01-1016 and GT-Power modeling done in SAE 2016-01-0565
   - Currently investigating effects of cooling system improvements and in-cylinder motion
2. **GT-Power modeling of a 2012 PSA 1.6 liter GDI-turbo-charged engine with cooled EGR and an advanced turbo**
   - Benchmarking work completed on base engine with Tier-2 and Tier-3 fuels, and a GT-Power model constructed (Tier-2 fuel only)
   - Cool EGR and VNT turbo modeled in GT-Power
   - Currently drafting benchmarking report and reviewing GT-Power model
3. **GT-Power modeling of a 2016 Honda Civic 1.5 liter GDI-turbo-charged 10.6:1 CR engine**
   - Benchmarking almost complete (see earlier benchmarking slide)
   - GT-Power model created based on benchmarking data
   - Plan to examine the effect of adding cooled EGR, improved cooling, and improved turbos
4. **ALPHA model comparison of several CVTs**
   - Initial ALPHA vehicle validation completed on the Honda Civic equipped with a CVT
   - Benchmarking completed on Nissan Jatco CVT8 and currently drafting report
   - Comparison of available CVT data is underway

Four New EPA SAE Papers Published in 2017

Available at: https://www.epa.gov/regulations-emissions-vehicles-and-engines/midterm-evaluation-light-duty-vehicle-greenhouse-gas-ghg

ALPHA Related SAE Journal papers:

1. **"Characterizing Factors Influencing SI Engine Transient Fuel Consumption for Vehicle Simulation in ALPHA,"** *SAE Int. J. Engines* 10(2):2017, doi:10.4271/2017-01-0533, Dekraker, P., Stuhldreher, M., Kim, Y. (SwRI).
   - *This paper addresses some of the transient engine operating conditions that must be considered to address shortfalls that can occur when simulating vehicle fuel consumption. It examines fuel adjustments for:*
     a) *Powertrain Torque Management*
     b) *Changes in Engine Power*
     c) *Deceleration Fuel Cutoff (DFCO)*
     d) *Cylinder Deactivation (CDA) Transition*

2. **"Fleet-Level Modeling of Real World Factors Influencing Greenhouse Gas Emission Simulation in ALPHA,"** *SAE Int. J. Fuels Lubr.* 10(1):2017, doi:10.4271/2017-01-0899, Dekraker, P., Kargul, J., Moskalik, A., Newman, K., Doorlag, M., Barba, D.
   - *The 1st part of the paper reviews the 3 steps EPA used to prepare for fleet modeling (benchmarking, validating ALPHA, and characterizing a core set of future powertrains)*
   - *The 2nd part of the paper shows how the above test data was generalized for use in modeling future fleets. Aspects of this generalization include engine scaling, transmission scaling, roadloads, cost-start adjustment for future vehicles, and performance neutrality.*

Four New EPA SAE Papers Published in 2017 (continued)

Available at: https://www.epa.gov/regulations-emissions-vehicles-and-engines/midterm-evaluation-light-duty-vehicle-greenhouse-gas-ghg

Component Related:

3. **"Potential Fuel Economy Improvements from the Implementation of cEGR and CDA on an Atkinson Cycle Engine,"** SAE Technical Paper 2017-01-1016, 2017, doi:10.4271/2017-01-1016, Schenk, C., Dekraker, P.
   - *This paper presents testing results from implementation of cEGR and CDA hardware on an Atkinson cycle capable engine*
     - *Open ECU and cEGR hardware was installed on base engine, a production 2.0L SKYACTIV-G engine with 75 degrees of intake cam phase authority and a 14:1 geometric compression ratio, and CO2 reduction effectiveness is evaluated.*
     - *Additionally, two cylinders were deactivated to determine what CO2 benefits could be achieved.*
   - *This test cell validation follows up on benchmarking and GT-Power modeling work described in two 2016 SAE papers (SAE 2016-01-1007 and SAE 2016-01-0565).*

4. **"Modeling and Validation of 12V Lead-acid Battery for Stop-Start Technology,"** SAE Technical Paper 2017-01-1211, 2017, doi:10.4271/2017-01-1211, Lee, S., Cherry, J., Safoutin, M., McDonald, J.
   - *This paper presents the development and validation of the lead-acid battery model.*
   - *Resistances and capacitances were calculated using test data from a Duracell 92Ah lead-acid battery which is aftermarket equipment for the Chevrolet Malibu.*
   - *The lead-acid battery library in the ALPHA model was validated with data obtained from Argonne National Laboratory (ANL) from their chassis dynamometer testing of the 2010 Mazda 3 Hatchback i-Stop and 2010 VW Golf TDI Diesel Bluemotion.*
   - *The simulated battery voltages, currents, and state of charge (SOC) are in excellent agreement with the vehicle test data on a number of drive schedules.*

Consumer/Economic Issues

- Consumer Acceptance
- Affordability
- Willingness to pay for vehicle attributes
- Vehicle sales
- Employment and economy-wide impacts

Consumer Acceptance: How do consumers respond to vehicles subject to the standards?

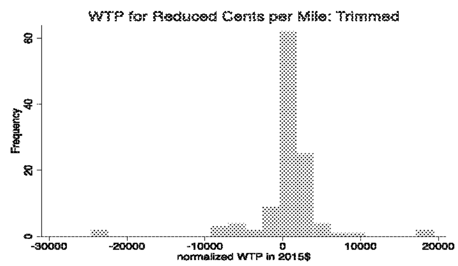
- Prior EPA studies indicate that consumers seem to be accepting of the technologies currently being used to meet the standards
- Industry comments have expressed concerns over acceptance of the future fleet related to vehicle cost increases as well as the degree of electrification required
  - More electrification means increases in vehicle cost, in addition to questions of consumer willingness to change technologies
- EPA continues to pursue access to a consumer satisfaction database to further assess consumer satisfaction, as some commenters suggested
- EPA is open to any new data/information on this issue

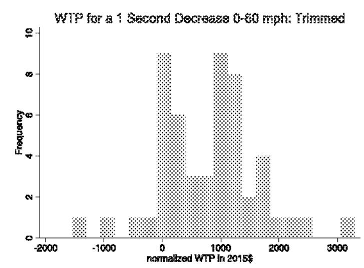
Affordability

- In comments and recent research, some key questions have arisen:
  - Are the standards regressive (i.e., putting disproportionate burden on low-income households)?
  - How will potential vehicle price increases affect consumer access to the vehicle market?
- Regressivity: 3 recent studies
  - 2 studies (Davis & Knittel; Levinson) found regressivity without accounting for fuel savings from the new technologies
  - 1 study (Greene & Welch) that accounts for fuel savings found that fuel economy improvements are progressive
- Vehicle price increases
  - Average vehicle transactions prices have increased in recent years
  - Seeking information to help identify contributors to price increases in addition to the standards (e.g. buying larger vehicles, or technologies such as safety features and connectivity that add to costs)
  - How might higher vehicle prices affect access to credit?

Willingness-to-pay for vehicle attributes

- A factor in understanding demand for vehicles includes the role of vehicle attributes in the buying decision
- EPA has been developing estimates of consumers' willingness to pay for vehicle attributes
  - See, e.g., presentation at the Society for Benefit-Cost Analysis annual meeting https://benefitcostanalysis.org/sites/default/files/public/C3.1%20Helfand%20et%20al%20WTP%20for%20veh%20char%2020170323.pdf
  - To date, estimates for attributes show very wide ranges
  - We are trying to understand why there is so much variation





Vehicle sales

- Some auto industry comments encouraged EPA to quantify effects of the standards on vehicle sales
- The key variable appears to be the role of fuel economy in consumers' vehicle purchase decisions
  - Estimates in published literature range from significant undervaluation to overvaluation, with no clear central value
- Sales estimates are very sensitive to this assumption
  - e.g., "A Macroeconomic Study of Federal and State Automotive Regulations," Carley et al.
- How can the effects of the standards be separated from the effects of broader macroeconomic changes?

Figure 9.4a. Impact of Consumer Valuation of Fuel Savings on Car Sales by Model Year.

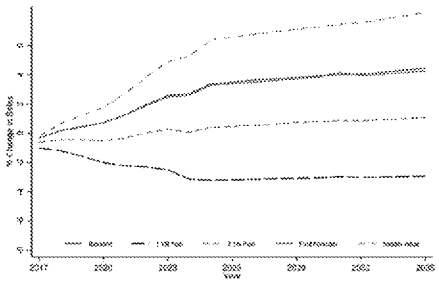
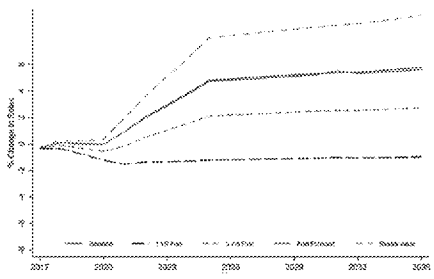


Figure 9.4b. Impact of Consumer Valuation of Fuel Savings on Truck Sales by Model Year.



Employment and Economy-wide impacts

- Several recent studies addressed employment and economy-wide impacts:
  - CAR, "The Potential Effects of the 2017-2025 EPA/NHTSA GHG/Fuel Economy Mandates on the U.S. Economy"
  - Indiana University: "A Macroeconomic Study of Federal and State Automotive Regulations"
  - Blue-Green Alliance, "Supplying Ingenuity II: U.S. Suppliers of Key Clean, Fuel-Efficient Vehicle Technologies"
- Auto industry comments on employment analysis suggested fuller quantification

- EPA's work on employment impacts to date has focused on the auto sector
  - Broader employment effects depend on the state of the macroeconomy

- EPA is exploring the use of economy-wide models to estimate broader macroeconomic effects
  - EPA has convened a panel of experts through the Science Advisory Board on economy-wide modeling to review these models, and expects a final report later this year
  - See https://yosemite.epa.gov/sab/sabproduct.nsf/0/07E87CF77B5473428525756B004F87ED?OpenDocument

Questions/Discussion